Final Report

California Information Display Pilot Technology Assessment

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Executive Summary

Mass-market electricity customers' behavior accounts for one-quarter to one-third of home energy use. Research over the past two decades has documented that useful feedback can result in reductions in energy use of 4 to 15 percent. Moreover, feedback is more useful when it is immediate and easily accessible rather than antecedent; e.g., provided with the monthly bill). Even monthly information, though, is useful, especially if the customers previously hadn't received any feedback other than the amount owed for the utility bill. But for dynamic electricity pricing, timely feedback is essential.

As part of the Information Display Pilot (IDP), Primen investigated devices for displaying dynamic pricing signals and immediate energy use and cost information. We assumed that the residential and small commercial customers participating in the IDP were, like most customers, not particularly focused on energy use or inclined to actively seek out feedback on energy use and costs. We researched energy use display devices but did not find any that were compatible with existing IDP customers' meters, could also display the energy cost information with the CPP-V rate, and were commercially available for deployment in July 2004.

As a result of this initial assessment, we decided to use a non traditional but commercial viable approach to meet the research goals of the project. To convey the CPP pricing signals and critical peak periods, we deployed an "Energy Orb," a small, grapefruit-sized glass globe that glows different colors. We programmed the orb to change colors when prices changed. The color would depend on whether the current electricity price was low (off-peak), medium (on-peak) or high (critical peak). The orb also flashed to give notice that a critical peak was imminent. Customers—especially those who felt they could take actions in response to price signals—liked the orb and found it useful.

Primen also completed a detailed examination of energy and pricing display devices as part of the IDP research objectives. We found numerous meter display devices that work independently of the existing IOU meter. Depending on the model, the units display some combination of instantaneous and cumulative energy use and cost. Some can also estimate monthly bills. Many models include alarms that emit sound or light when energy use or cost exceeds pre-set limits. Some of the displays are hard-wired to the CT (current transducer) and therefore are located near the circuit panel. Others use wireless or powerline communication, allowing the display device to be located anywhere in the home or business.

Many of these devices available today can show instantaneous electricity use, but none accurately reflect electricity costs under a critical peak pricing- variable period (CPP-V) tariff. This is because they don't have built-in network communications and therefore cannot indicate when the critical peak price is in effect. Most of them are designed to work with a flat rate, and there are some models that can be programmed for fixed time-of-use or demand rates.

Another category of metering display devices requires changing out the meter or installing a submeter. Some of these electronic meters can communicate data wirelessly or over the powerline to display devices. Prepayment meters already provide in-home information on current spend rate and number of hours/days left. Meters currently in development can provide instantaneous, daily, and month-to-date use and cost. Many existing electrical meters can be programmed for time-of-use (TOU) or demand rates. Unless the metering system has some kind of communications with the utility, though, the display device will not be able to accurately reflect energy costs during critical peak times. These systems would need to be compatible with an Automated Meter Reading (AMR) system to receive daily price signals, or without AMR could incorporate a paging receiver.

Most of the traditional metering and specialty meter device providers we interviewed indicated that adding communications to show instantaneous energy use and cost under a CPP tariff was not a technical challenge. The devices do not include communications because vendors have been trying to keep the costs down for traditional applications. Although the providers haven’t looked into the issue extensively, one-way paging or utilizing existing IOU network communications was often mentioned as a relatively inexpensive way to receive a signal of critical peak in the absence of AMR. If needed, vendors think that the communications functionality necessary to support a CPP rate could be incorporated fairly easily into the existing metering designs, with devices available within 6 to 9 months of an order.

Background

The California Statewide Pricing Pilot (SPP) is a demand response scientific experiment designed to test the effectiveness of three experimental dynamic pricing tariffs – time of use (TOU), critical peak pricing, fixed period (CPP-F), and critical peak pricing, variable period (CPP-V). The tariffs have fixed prices that vary according to the time of day for the TOU customers, and during special peak pricing events for the CPP customers. CPP customers receive a telephone notification either a day ahead or four hours prior to a critical peak pricing event, during which the price of electricity is significantly higher than their normal TOU daytime rate.

In this report, “customers” refers to residential and small commercial (<200 kW peak demand) customers.

Information available to the participants in the SPP is provided by the utilities sponsoring the project, and includes:

- A customer “welcome package” that explains the program
- Monthly billing statements that are delivered by mail
- A bi-annual bill comparison, which compares the customer’s energy costs on their current dynamic rate to a “what if” scenario based on their original rate
- Next-day access to their daily usage via the Internet

Customer responsiveness to the tariffs in the SPP is being measured through participant surveys and electrical usage, and an index of their “elasticity” to the pricing schedules is being calculated using econometric models. After preliminary results were analyzed in 2003, the SPP advisory committee believed that additional direct feedback and dynamic tools could possibly enhance the customer benefits and improve the effectiveness of the tariffs.

As a result, a special additional experiment called the Information Display Pilot (IDP) was designed and implemented with a subset of customers on the CPP-V rates to test whether giving these customers better information about energy prices and enhanced feedback about their energy use would result in greater reduction during critical peak periods.

Specifically, the IDP was set up to investigate five sets of research questions. This report addresses two of them.

- What is the potential for real-time feedback and/or detailed consumption analysis beyond what the Joint Utilities are offering in the SPP and within the schedule for the SPP timeline for significant analysis?

- What types of enhanced feedback information technologies are currently available for dynamic pricing? What types of information feedback tools are available to customers and what are their costs?

To answer these questions, Primen identified and reviewed relevant information technology and information treatments that could be used in the IDP program. We also reviewed the literature and conducted interviews with vendors and consultants to assess technology design trends, and find previous studies about information treatments and their effectiveness in modifying customer behavior and electrical usage.

What is the Potential for Real-Time Energy Feedback?

The concept and application of giving customers real-time feedback on how much energy they're using in order to get them to modify their behavior is not new. By real-time, we mean instantaneous feedback that customers can see and understand. It might be displayed on a meter or other device in the home or business. It is not defined as logging on to a website to see interval data updated daily. Researchers have studied the effects of both direct and indirect feedback for energy conservation for years, and have asked the vendors of electrical metering devices to provide feedback displays in some manner for almost as long.

This section of the report details the technical potential for reduction in energy use resulting from real-time feedback devices. It is important to note that most of the studies relate to reductions in energy use for customers of flat rates. The effect of feedback on residential and small-commercial customers who are on dynamic rates does not appear in the literature.

Feedback serves two purposes: 1) it fills a knowledge gap; and/or 2) it can be used to motivate behavior, guiding goal attainment. Based on the research studies noted below, feedback to customers on energy use can result in reductions in consumption from 4 to 15 percent.

Feedback appears to be most useful when accompanied by a specific goal, such as reducing energy use by 10 percent:

- An experiment in the Netherlands involved giving 50 households in-home displays of gas use (called the Indicator). The Indicator corrected for degree-days so residents could tell weather-related effects apart from behavior-related effects. Residents had a goal of 10 percent energy use reduction. With the Indicator, they reduced natural gas use by over 12 percent. (Van Houwelingen and Van Raaij, 1989).

The habits of home residents greatly affect overall energy use:

- 33% of home energy use in US is attributable to residents' behavior (Sonderegger, 1978)
- 26% of home energy use in Netherlands is attributable to residents' behavior (Verhallen et at, 1981)

Even providing monthly feedback results in reduced energy use:

- In a study of 105 district-heated homes in Finland, energy consumption for space heating decreased 3 – 9 %after customers received monthly feedback. Electricity consumption decreased 17 – 21%. (Haakana et al, 1997).
- In a survey for Energy Star Billing, Delaware residents were asked what they would do if they received an Energy Star Billing graph showing high usage. 44% of respondents indicated they would make some changes, such as turning off lights or using the dryer less (Bengtson, 1997).

The time between the behavior and the feedback on the resulting energy use and cost (action and consequence) is very important.

- The sooner the feedback is delivered, the more effective it is (Seligman et al, 1977).
- Daily feedback has an impact on heating and cooling. Continuous feedback affects other energy uses (McClelland and Cook, 1979).

It is worth noting that in the late 1970s, when energy conservation research was just developing, electronic meters, programmable thermostats, and other tools for providing or responding to feedback weren't widely available. Customers relied more on educational tips and estimates of savings related to specific actions to guide them for the right actions to take. Their belief in that they had taken the "right" action was an immediate self-reinforcement, even in situations when the electric bill did not change a month later.

In-home displays can give customers access to energy use and cost information in real-time. This is important because the customers can actually see the costs of using various equipment or appliances in the home. They can see high costs (or projected high costs) and make changes in their behavior, rather than seeing an end-of-month high bill, making some changes, and then waiting for the next bill. This ability to do something different as soon as possible to avoid a high bill is especially important with dynamic pricing.

- A study of in-home displays in Canada found savings of 4-5% (Hutton et al, 1986)
- Customers refer to in-home displays less frequently after the first few months (Hutton et al., 1986)
- Nonetheless, savings do not necessarily persist after the devices are removed (Hutton et al., 1986)
- A study of 44 UK households found that giving customers in-home displays for cooking energy only resulted in average reductions of 15%. Giving them only antecedent information reduced consumption by 3%. (Wood et al., 2003)
- In Norway, customers with feedback reduced energy use by about 9% (Notes from Ofgem seminar, 2004).

- Northern Ireland Electricity has keypad meters (prepayment) installed for about 20% (125,000) of their customers. With training, customers reduced consumption by 11 percent. Customers who received keypad meters without instruction still reduced consumption by 4 percent (Graeme Hunter, NIE presentation, undated and personal communication 10/26/04).

When applying these results to present-day California and the SPP, it is important to make note of circumstances that may have changed since the research was performed. First, most of these studies were conducted with customers on flat, or non-dynamic, rates. There is little experience of providing customers with feedback on their consumption on dynamic pricing. The potential lack of motivations for quick feedback and response, as well as the lack of a dynamic price signal, can affect the transferability of these studies to the current research.

Second, expectations about the availability and frequency of information are vastly different now that in the 1970s and 80s, when much of this research was conducted. Information flows have changed dramatically since that time. The Internet, widespread wireless communications, cell phones, and paging are all commonplace now, but were not available then. Thus, we hypothesize that customers would both want and expect better information about energy use. Likewise, technologies that can automatically reduce or shift energy use are much more common now than they were 25 years ago.

We cannot say definitively how these two changes have affected customer desire for and ability to respond to energy use feedback, but speculate they would make the effects of feedback for an “information hungry” customer even more pronounced.

Kinds of Energy Information Feedback Tools

Primen focused on communication of two types of energy information: energy prices and energy use. For the SPP program (and specifically the CPP-V rate), the time-of-use prices are known in advance, although when the highest price will occur (the Super Peak Period) is not. The prices are fixed for customers on the CPP-V rate. Energy use, of course, varies depending on the behavior of the occupants and the appliances and end uses. The actual resulting cost of the energy being used depends on both usage and the price. We consider energy cost in the same category as energy use, since it is unique to each customer.

In our research, we looked for technologies that:

- Met minimum criteria for IDP deployment and were not redundant with existing utility information treatments or programs

- Were affordable to deploy and had the potential for wide-scale deployment

- Were compatible with existing metering and communications systems at SPP customer sites.

Specifically, information feedback devices needed to be able to show energy cost throughout the day, including critical peak periods, which are dispatched with as little as four hours' notice. The existing billing meters collected 15-minute interval data and sent it to the utility once a day. They were not designed to allow the customer access to the data throughout the day.

Energy Prices

We first looked at ways to communicate the price signal to the IDP participants throughout the day. The basic off-peak and on-peak structure is simple (on-peak Monday-Friday from 12-6 pm for commercial customers and 2-7 pm for residential customers and off-peak at all other times). Critical peak periods can occur 15 times a year during the on-peak period and last either 2 or 5 hours. The customer is notified four hours before the critical peak time is to start. Current SPP participants receive a "welcome package" that lists the pricings and time periods, and gives examples of what could be done to reduce costs. There is also a refrigerator magnet with the on-peak time period indicated that is distributed for general awareness.

Although the price structure is not terribly complex, paying attention to prices is new, so we looked for a technology that would remind customers of prices. Since there are only three prices (off-peak, peak, and super-peak) in the CPP-V structure, we felt it was not necessary to convey exact prices to raise customer awareness. Instead, we looked for technologies that could convey the notification of the timing of these three different prices levels relatively simply and easily.

Energy Orbs

We found an existing technology that had the potential to notify energy prices in a clear, appealing, and unusual way. Originally designed as an entertainment device to indicate the status of the stock market, that technology is the Energy Orb, a glass globe that glows different colors in response to a wireless paging signal. (See **Figure 1**.) We purchased the original stock orbs, reprogrammed the paging system that communicates with the orbs to indicate the prices of the CPP-V rate, and installed them in customers' homes and businesses. Many customers liked the Energy Orbs, and found them interesting and engaging. The IDP customer and non-participant reaction to Energy Orbs is included in the IDP Evaluation Report.[1]

[1] "Information Display Pilot: California Statewide Pilot," submitted by Nexus Energy Software, Opinion Dynamics Corporation, and Primen to the California Energy Commission. Draft final report dated December 18, 2004.

Figure 1: Energy Orb

This Energy Orb is installed at Beanscene Espresso in Los Angeles.

Source: Geltz Communications

How Energy Orbs Work

The Energy Orb is actually an off-the-shelf consumer electronics technology from Ambient Devices. They sell the orb (called the Stock Orb) to indicate the Stock Market status by communicating to the orb to change colors. Inside the globe is a wireless paging receiver and colored LEDs (light emitting diodes). The orb is programmed to “listen” to this specific set of radio signals and the only installation required is plugging the orb into a wall outlet for power.

As an option, owners of the orb can log into a website and subscribe to other indexes (weather, Homeland Security) or can reprogram their orb to receive customized commands. Primen utilized this customized channel programming to convert the Stock Orb into an Energy Orb for the purposes of the IDP.

Energy Orb Colors

We programmed the radio-paging server to send a signal to operate the Orbs to show the status of the CPP-V energy prices, and to notify the customers when critical peak was imminent:

Blue: off-peak (mornings, evenings and weekends/holidays)

Green: peak (weekday afternoons only)

Red: super peak (during test events and system emergencies)

Flashing red: warning of imminent super peak, beginning four hours before super peak events.

We had originally planned to use the intuitive green/yellow/red color scheme (traffic signal protocol) for the off-peak/peak/super peak prices. However, we found the yellow color from the LEDs in the Energy Orb to be pale and difficult to distinguish from green (yellow is made by lighting both green and red LEDs), so we used the blue/green/red combination.

Calm Technology

Why was initial customer response to the Energy Orbs so positive? Customers didn't have to stop what they're doing and go to a website or peruse a list of numbers to understand electricity prices. The intuitive, unobtrusive, easily accessible display of information is known as "calm technology." Calm technology, which would both encalm and inform, was the vision of Mark Weiser and John Seely Brown of Xerox PARC.[2]

The premise of Calm Technology is that people can take in information at the periphery, as effectively as maintaining direct focus. For example, when driving, the car engine makes noise, but we scarcely hear it. Instead, we are tuned in to the conversation, our thoughts, or music from the radio. As soon as that engine noise changes, though, we're instantly aware, and shift our attention to focus on it. This shifting of attention back and forth between periphery and central focus is the hallmark of calm technology.

This concept appeals today to many people who feel "on" all the time. Although people can be connected to direct stimuli (radio, TV, cell phone, pager, etc.), they can also receive and process information on the periphery. The current "overload of information" provides new appreciation for the utilization of peripheral notification.

Interestingly, Calm Technology is similar to the information displays of 50 years ago or more, when there was little connectivity and people relied on easily viewed visual symbols. A childhood icon comes to mind: the Weather Ball. The Weather Ball perched on top of the Northwestern Bank Building in Minneapolis. It was installed in 1949, and remained there until 1982 when the building burned. Want to know the weather in Minneapolis?[3] No need to find a radio and wait for the top of the hour. Just look. Residents all knew the jingle:

> *When the Weatherball is red, warmer weather is ahead.*
>
> *When the Weatherball is green, no change in weather is foreseen.*
>
> *When the Weatherball is white, colder weather is in sight.*
>
> *If colors blink by night or day, precipitation's on the way.*

Fifty-five years later, the Energy Orb technology communicates price information in a very similar display. Indeed, one of the available commercial channels for the Orb shows current temperature and the Ambient Beacon (a cube version of the Orb) shows forecasts by color. Everything old is new again.

[2] See Weiser, Mark and John Seely Brown, "Designing Calm Technology," Xerox PARC (December 21, 1995) http://www.ubiq.com/weiser/calmtech.calmtech.htm and Weiser, Mark and John Seely Brown "The Coming Age of Calm Technology," Xerox PARC (October 5, 1996) http://www.ubiq.com/hypertext/weiser/acmfuture2endnote.htm.
[3] See Weiser, Mark and John Seely Brown, "Designing Calm Technology," Xerox PARC (December 21, 1995) http://www.ubiq.com/weiser/calmtech.calmtech.htm and Weiser, Mark and John Seely Brown "The Coming Age of Calm Technology," Xerox PARC (October 5, 1996) http://www.ubiq.com/hypertext/weiser/acmfuture2endnote.htm.

Other Ways to Display Price Signals

Several other devices can be used to display price signals, ranging from stoplights to plug-in LED indicators. We did not install any other price display devices other than the Energy Orb. We did test one other, the Comverge Customer Alert Device (CAD), in focus groups. The CAD is a four-inch square radio-paging receiver that plugs into a wall outlet and has three small LEDs in three colors (red, green, and yellow) on the faceplate. It looks much like a plug-in smoke detector, and even has an audible tone that can be programmed to beep or chirp in conjunction with the lights.

There are numerous other price notification displays, but they tend to be incorporated in either a unique pilot program technology, beta prototype designs, or as part of energy pre-payment or pay-as-you-go metering system. We did not find others that were available in summer 2004 and that could display energy costs incurred through time-varying rates. Although some in-home metering displays exist in Europe (as part of the utility's TOU tariff) these were not available for use in California. Over the years of electricity pricing and behavior research, displays have ranged from the simplicity of a small light on an appliance to the more complex home automation systems that displayed daily prices in residences.

We present a few intriguing examples here of ways to display price signals, for information and possible future adaptation:

- Stoplight. PG&E put together a signal for pricing in the late 1980s. PG&E ran a dispatchable rate pilot for small commercial and industrial customers (SCIP-- Small Commercial and Industrial Program). Customers were on a flat rate. During certain times, PG&E would dispatch a critical rate, with a minimum of one hours' notice. Program Manager Bill LeBlanc used a stoplight to convey prices. The light was green most of the time for the standard flat rate. Yellow meant a critical peak was coming and red meant critical. LeBlanc used a novelty stoplight from a retail outlet (smaller and lighter than the real thing). It was triggered by a signal sent over the existing 154 MHz load control network.[4] Customers liked the stoplight and found it easy to respond to.

- Electricite de France (EDP) offers the Tempo rate. Days are designated blue (lowest price, 300 days), white (medium price, 43 days) or red (highest price, 22 days). Each day has fixed peak and off-peak hours. The day type is determined at the end of the day for the next day. EDF uses a simple notification box that plugs into any power socket to indicate the day's color and the current hourly cost.[5] In a pilot program with 800 customers, the average daily consumption was reduced by 15% on white days and 45% on red days. Participants shifted 30% more energy use from peak to off-peak times on white days as compared to blue days, and shifted even more on red days.

[4] Bill LeBlanc, personal communication (December 7, 2004), President, Boulder Energy Group, 907 Brooklawn Drive, Boulder, CO 80303. Tel: 303-668-2977. email billleblanc@comcast.net.
[5] "Results from the EFFLOCOM Pilots," EU/SAVE 132/2001, June 30, 2004. Available from http://www.efflocom.com (Report No. 7).

- Data fountains, developed by Netherlands artist Koerte, vary the height of water to convey information. (Think of the fountains at the Bellagio in Las Vegas, but set to data instead of music. See **Figure 2**.) One data fountain already built compares the exchange rates of the dollar, euro, and yen. (www.datafountain.com)

Figure 2: Data Fountain

Source: datafountain

- Laughing Lily is designed to facilitate meetings to run more smoothly. Frequently, either too many people talk at once, interrupting each other, or there is silence. The Laughing Lily is a flower that wilts when there is too much or too little noise. (Antifakos, 2003)

- Colored computer monitor. Apple has a patent for a computer monitor frame surrounded by LEDs embedded in clear plastic. The frame can change color depending, for example, on whether you have email from your boss or your spouse.

In-Home Displays of Energy Use/Cost

The second type of information to display is current energy use and cost. An in-home display of energy use or cost provides immediate and intuitive feedback. Turning on a light or an electric stove increases energy usage and causes the display to change significantly. The display system collects data from the meter or circuit panel, so it can register all energy use in the home or business. It is virtually impossible to get the displays to read zero. Indeed, with everything off, it is easy to see the amount of electricity consumed by electronics that are in the "off" position.

We did not install any of these types of displays during the IDP because:

1) There were no devices in the commercial market that were both suitable for installation within the IDP customer base and compatible with existing metering infrastructure.

2) The technologies that were available off-the-shelf in summer 2004 that worked with existing metering infrastructure could not display energy costs for the CPP-V rate structure. They all worked with a flat rate.

3) The expedited timeline required devices that were available and ready to install off-the-shelf.

The only device that claimed to be capable of showing energy costs associated with the CPP-V rate structure was the USCL EMS-2020. A demonstration was available by July 2004, but working models had not yet been installed. In addition, the EMS-2020 requires replacement of the electric meter, and installations were limited to those that could work with existing CPP customer metering.

Of the clip-on type devices, none could accommodate the CPP-V rate structure. Several of the manufacturers said they could add a clock and show costs for a TOU rate. Making that change would require an order of several thousand units and take 4-8 months, and even so would not be able to show costs during critical peak events. A few makers of the clip-on type devices were planning product launch for late 2004 or early 2005.

While there are several manufacturers of in-home displays, or products that could be modified to provide in-home displays, the expedited timeline for IDP deployment necessitated technologies that could be quickly and effectively deployed. It did not allow for modifications and the extra care that technologies new to market require. Given more time and with proper development, there are some potentially good energy display systems, but our schedule did not allow for standard testing. (See **Table 1**.)

Table 1: In-home Display Technologies

Technology	Company	Contact Info	Description	Typical Use	Status	Purchase Cost	Installation Cost
Cent-a-Meter	Island Power Pty Ltd. (Cenergies in US)	Colin Kelly Director/Business Development Island Power Pty Ltd (Whitesands Limited - Distribution Vehicle for USA operations) Email: colinkelly@smartchat.net.au Tel: 61 2 4963 1241 Kent E. Nelson President Cenergies Unlimited 9501 Cargo Avenue, Suite 100 Austin, Texas 78719 Tel: 512-215-4332 kentnelson@cenergies.com www.cenergies.com	▪ Clip-on technology ▪ Movable in-home display (wireless) ▪ Instantaneous $, kWh, temperature, humidity, greenhouse gas emissions	▪ Learn baseline and monitor ▪ Check unit before leaving house to make sure everything off ▪ See cost of running appliances	~ 9000 sold in Australia and New Zealand. US launch planned for early 2005.	~ $100-150	~ $75-200 (electrician or contractor)
EUM-2000	Energy Monitoring Technologies	Juan Gonzales President Energy Monitoring Technologies 7516 NW 55 Street Miami, FL 33166 Tel: (305) 470-9716 Email: jgonzalez@energymonitor.com http://www.energymonitor.com	▪ Clip-on technology ▪ Display hard-wired to panel ▪ Instantaneous $, kW; bill projected energy bill, alarm	▪ Learn baseline and monitor ▪ Monitor projected bill	~10,000 devices installed.	$225 (whole house) or $175 (apartment)	~ $75-200 (electrician or contractor)
The Energy Detective	Energy, Inc.	Dolph Rodenberg President P.O. Box 415 Mt. Pleasant, SC 29465 Tel 843-849-7008 info@theenergydetective.com www.theenergydetective.com	▪ Clip-on technology ▪ Movable display (powerline carrier) ▪ Instantaneous $, kW; day, month-to-date and projected monthly $ and kWh ▪ Voltage ▪ Alarms ▪ LEDs ▪ Programmable for various rate structures (TOU, fixed bill component, taxes, etc.)	▪ Learn baseline and monitor ▪ Check voltage ▪ Estimate bill ▪ Store data and download for additional analysis	Product launch planned for early 2005	~ $100-150	~ $75-200 (electrician or contractor)

Technology	Company	Contact Info	Description	Typical Use	Status	Purchase Cost	Installation Cost
			▪ Stores 2 months worth of hourly data, can be transferred to computer				
Greenwire Energy Monitor	Greenwire LLC	Mark Palasz President Greenwire LLC 907 Sweetwater River Drive Austin, TX 78748 Tel: 512-914-4931 Email: mark.palasz@greenwirellc.com	▪ Energy-use sensor installs outside of existing electric meter ▪ Display device communicates via wireless RF ▪ Displays last 24 hours' cost and use ▪ Displays instantaneous use (kW) in graphical form (bar chart or pace of blinking lights).	▪ Learn baseline and monitor ▪ Check unit before leaving house to make sure everything off ▪ See cost of running appliances	Product launch planned for 1Q 2005	~$50 target price	$0 (done by customer)
Power Cost Display Monitor	Energy Control Systems	Bill Littlehales CTO and Inventor Energy Control Systems P.O. Box 3360 Incline Village, NV 89450-3360 Tel: (775) 831-0727 Mob: (775) 771-3649 Email: wmlit@aol.com energycontrolsysinc.com	▪ Transmitter collar installs behind meter ▪ Display device communicates via powerline, can be located anywhere ▪ Displays cost only ▪ "Cost" shown is monthly cost if all loads currently on ran for entire month	▪ See cost of running appliances	A few devices installed	$380 in small quantities	Few minutes of utility electrician's time to pull meter, set transmitter, replace meter
kWh Meter	E-Mon (MeterSmart)	Frank Russell MeterSmart 2212 Arlington Downs Road, Suite 204 Arlington, TX 76011 Tel: (831) 801-7758 Email: frussell@huntpower.com www.metersmart.com www.emon.com	▪ Highly accurate submetering ▪ One-line display shows instantaneous energy use ▪ Does not display cost ▪ Also measures waveforms and other power quality variables	▪ Designed for submetering, not display ▪ View instantaneous use ▪ Can download data to computer for additional analysis	Proven technology, thousands of devices installed	~$300	$75-200
Customer Interface Display	Dent Instruments	Chris Dent President Dent Instruments 64 NW Franklin Avenue Bend, OR 97701-2906	▪ Display communicates with meter via powerline, can be located anywhere ▪ Install with meter replacement (Dent's PowerPal, based on	▪ Learn baseline and monitor ▪ See cost of running appliances	Piloting with Tacoma Power	~$300 for meter plus ~$250-280 for Customer Interface	Few minutes of utility electrician's time to replace meter

Technology	Company	Contact Info	Description	Typical Use	Status	Purchase Cost	Installation Cost
		Tel: (541) 388-4774 Email: cdent@DentInstruments.com www.DentInstruments.com	Sensus iCon) ▪ Display queries meter for energy use			Display	
PowerStat	DCSI	Mark Day DCSI 945 Hornet Drive Hazelwood, MO 63042 tel 314-895-6510 mday@twacs.com www.dcsi.com http://www.twacs.com/Support/2004%20Spec%20Sheets/PowerStat.pdf	▪ Prepayment meter and display ▪ In mid 1990s, field trial of in-home display with existing meter ▪ System not currently available ▪ DCSI has AMR, load control, prepayment and display capabilities	▪ Learn baseline and monitor ▪ See cost of running appliances ▪ Monthly bill projection ▪ Alarm if exceed budget or during peak times	Display without prepayment not currently available, though did pilot with PacifiCorp in mid 1990s	NA	NA
EMS-2020	UCSL	Tom Tamarkin President 2737 Eastern Avenue Sacramento, CA 95821 Tel: 916-482-2000 Email: tdtamarkin@usclcorp.com http://www.usclcorp.com	▪ Collects data from revenue meter ▪ Two-way communications, between utility and EMS-2020 provide ability to handle complex, dynamic rates ▪ Moveable in-home display (wireless) ▪ Displays instantaneous use (kW, kWh and $), day, month-to-day ▪ Calculates monthly budget ▪ Alarm when use exceeds preset use or budget ▪ Displays data for electric, gas and water ▪ Part of full AMR system with associated features (remote read, connect/disconnect) ▪ Matches utility bill exactly	▪ Learn baseline and monitor use ▪ See cost (burn rate) of running appliances ▪ Monthly bill projection ▪ Alarm if exceed budget or during peak times	360 currently being installed in Los Angeles County	Cost is dependent on scale. $250/home (for 400 units) includes meter and EMS-2020 Projected ~$175/home for 10,000 units RF network $10-30/meter	Few minutes of utility electrician's time to replace meter

In addition, there were technical challenges with incorporating display technologies with the existing systems used by the IDP customers. Some metering display systems, such as those used with prepayment, are packaged together with the meter. To install such a system would have meant replacing the CPP meter, which was necessary for the CPP billing and existing IOU web presentation of usage.

Technically, it is possible to install separate meters for the purpose of providing feedback to customers. Institutionally, though, that raises a few problems. First, there is the added expense of duplicate meters. Second, if the customer has two different sources of data, it is at some point likely that they won't agree exactly, and the utility may need to explain the discrepancy. For this very reason, one of the in-home display devices does not show a month-to-date energy cost, even though customers are very interested in that feature. The utility that helped develop the display intentionally omitted that function because they didn't want to have to explain why the display didn't match the bill.

By far the majority of in-home displays are made to show energy use and energy cost *if the customer is on a flat rate*. They can be somewhat easily adapted to account for a time-of-use rate. That would require adding a clock chip and programming in two different rates. However, showing accurate costs on a critical peak rate is more complex and requires that the display device be capable of two-way communications so it can receive either notification of critical peak or an actual price signal from the utility.

We group the various display technologies by means of data collection.

In-Home Displays that Work with Existing Metering

There are several meter and electronics manufacturers working on relatively simple in-home displays that collect consumption data by a clip-on current transformer (CT) at the electrical panel. Others work with the existing meter, either collecting data from an attachment to the outside of the meter, or via transmitter installed between the existing electric meter and the utility meter socket. The displays are fairly small and look reassuringly familiar to customers—much like a temperature display. They display a variety of use and cost metrics (typically current, daily, and month-to-date). They have only a few buttons and can be "easily" programmed by the customer, providing s/he knows the right combinations and sequences of buttons to press. (Similar to the programming complexity to the functions of a digital watch, including alarm and stopwatch functions.)

An in-home display is a quick and easy way for consumers to see what it's costing to actually run their appliances. If the devices offer cumulative readouts, the consumer can see what the electric bill to date is and even project the bill for the end of the month. These devices are relatively inexpensive and easy to install. Costs to purchase range from $100-250 (although some devices not yet to market are aiming for costs as low as $50). Because installation of clip-on CTs requires removal of the front of circuit breaker housing, an electrician is recommended, though perhaps not strictly necessary. One vendor recommends an electrician, another posts installation directions on their website. Estimated installation costs for clip-on technologies are $75-200.

Devices include: Cent-a-Meter, EUM-2000, The Energy Detective, Greenwire Energy Monitor, Power Cost Display Monitor, Customer Interface Display, PowerStat, EMS-2020 These companies are relatively small. None has experience delivering units in large volumes. Chief differences among these devices are location and communication mode between display unit and panel and the format for displaying cost information.

The main drawback of these devices is that they are set up to show energy costs for a single rate (average electricity cost), so cannot show the cost of running an appliance at a super-peak time as compared to an off-peak time. The manufacturers say they could relatively easily add a clock chip and accommodate a two-part TOU rate. However, they do not have communications, so cannot indicate costs during a critical peak period.

Some of the manufacturers (Energy Monitoring Technologies, The Energy Detective) measure voltage and current and correct for power factor. Others (Cent-a-Meter) measure current but have customer input voltage. Such devices do not measure reactive power accurately and also cannot account for voltage fluctuations. As long as the inaccuracy is consistent, it shouldn’t present a problem to residential customers, who will be gauging relative energy use and reductions resulting from turning off appliances.

The following section describes specific brands of clip-on devices:

Cent-a-Meter (Island Power and Cenergies)

Description

The Cent-a-Meter is an in-home display device. It looks similar to a digital clock (see Figure 3). The user inputs an average electricity rate and the Cent-a-Meter shows current use (kWh) and cost ($). It does not totalize usage, so a cost-to-date for the month is not available. This feature was deliberatively omitted, as the utilities that use the Cent-a-Meter in Australia did not want the customer to be able to check and question the utility bill.

Programming is minimal and, if one reads the instruction manual, fairly straightforward. Viewing the various displays is accomplished by pushing just a few buttons. It displays: cost ($), use (kWh), temperature, humidity, and greenhouse gas emissions.

Figure 3: Cent-a-Meter

Source: Cent-a-Meter

Company and Experience

The Cent-a-Meter is made by Island Power Pty Ltd (an Australian company). The product has been actively promoted for less than a year (January 2004 launch in Australia and May 2004 launch in New Zealand) but has garnered a lot of local publicity. It has been featured on TV news spots, was a finalist for the Australian Museum Eureka Prize,[6] and is reportedly popular with customers. Many customers use it to make sure everything is turned off. They learn what their regular use is. Before leaving home, they check to make sure the use is about that; if it's more, they go back to see if they've left something on. As of October 2004, over 9,000 have been installed in Australia and New Zealand, though retail outlets, distributors, and utilities. Australian utility AGL offers Cent-a-Meters from its webpage.[7] A US launch is planned for early 2005. In the US, the Cent-a-Meter will be distributed through a newly formed Austin, Texas-based company, Cenergies.

[6] The Australian Museum Eureka Prizes are "awarded to a business, company or corporation which, through innovation or outstanding commitment to research, development or training, has sought to elevate corporate responsibility for scientific endeavour to a level consistent with our national capacity and needs." http://www.amonline.net.au/eureka/industry/2003_finalists.htm.

[7] See http://www.agl.com.au/AGLNew/Your+home/Energy+efficiency/Cent-a-Meter.htm.

Installation

Installation requires a licensed electrician. CTs are attached at the circuit panel. The wires go to a transmitter mounted on the wall near the panel. The battery-powered display unit can be placed anywhere in the home and moved as desired.

Differentiating Features

The Cent-a-Meter display is large and easy to read. It is wireless and battery-powered, so can be moved around the house. There is a transmitter mounted neared the circuit panel.

The Cent-a-Meter displays temperature and humidity. It also displays a conversion of energy to greenhouse gas emissions (not a big selling point for the US market, but of interest in New Zealand and Australia).

Unlike the other in-home displays that use CTs, the Cent-a-Meter does not measure voltage. The CT measures amps and is accurate to +/- 5 percent. The user inputs the voltage. The measured use (actually calculated by multiplying measured amps by stipulated voltage) accounts for neither voltage fluctuations nor power factor correction. It is therefore less accurate for reactive loads or locations with under, over, or variable voltage. As noted above, this inaccuracy is not likely to be very noticeable to the customer.

Cost

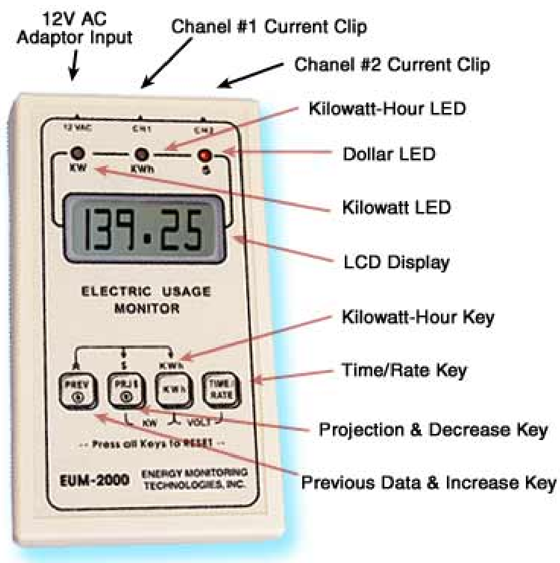
The Cent-a-Meter will be priced at $100-150 US. Installation costs would vary with location and the contract negotiated between utility and installers, likely in the $75-200 range.

EUM-2000 (Energy Monitoring Technologies)

Description

Energy Monitoring Technologies' display device, the EUM-2000, is also fairly simple, though a bit more complex than Cent-a-Meter's, and it is rated with more accuracy. It displays both instantaneous energy use (kW) and cumulative energy use (kWh) and cost ($). It also calculates a projected energy bill and can show an alarm if projected monthly bill or peak demand exceed preset levels. Like all the other CT-based displays, it uses only one electricity rate, so cannot show cost for TOU or CPP rates. The display is wired to the CT, so must be located near the circuit panel.

Figure 4: EUM-2000



Source: Energy Monitoring Technologies

Company and Experience

Two former utility employees founded energy Monitoring Technologies in 2000. Based in Florida, it currently has 12 employees and about 10,000 devices installed. EMT sells to distributors and directly to end-users. EMT is talking to several utilities, but has not yet sold to them.

Installation

Installation requires an electrician. CTs are attached at the circuit panel.

Differentiating Features

The EUM-2000 uses a split-core CT that measures both volts and amps, so it can measure and account for power factor accurately. The split-core CT has 7500 turns and is accurate to +/- 1%.

The EUM-2000 is most often used in the monthly bill projection mode. It calculates average use/minute month-to-date and calculates the projected monthly bill. Use and cost for each of the past 60 days is stored and accessible.

Versions of the EUM-2000 are also available for individual appliances, apartments, as well as the whole-house monitor.

Cost

The EUM-2000 costs $225 retail for a whole house monitor. An apartment version (one current clip instead of two) costs $175. Installation costs would be similar to other CT-based devices, dependent on local electrician costs but about $75-200.

The Energy Detective (Energy, Inc.)

Description

The Energy Detective (TED) by Energy, Inc. shows instantaneous kW and month-to-date kWh. It also projects what the use at end of month will be. It is somewhat programmable for complex rates (time-of-use and demand, but not CPP-V). TED communicates the data via powerline to the display unit, which can be moved and plugged into any outlet. Data displayed include: instantaneous use (kW and $), use today (kWh and $), use month-to-date (kWh and $), projected monthly bill, peak demand (kW and $), voltage (current, highest and lowest today), and current electricity rate. It also has an alarm that can be programmed in various ways: if cost/hour or kW/hour exceed limit, if $ or kWh per day or month-to-date or monthly projection exceed limit, and for low or high voltage.

Figure 5: The Energy Detective

Source: Energy, Inc.

Company and Experience

TED is a relatively new company, founded in 2002. ORNL was involved in the development of TED. At the end of 2004, the first units were in production. TED plans to begin marketing to utilities and home stores in 2005. TED is also working with homebuilders to get the devices installed in new construction.

Installation

Like others clip-on devices, requires electrician to install the CTs. Data is communicated to display device over powerline. Display can be plugged into any standard electrical outlet.

Differentiating Features

The design is very simple and easy to read. TED displays instantaneous and month-to-date energy use and cost. It also has an audible alarm and red and yellow LEDs. TED stores 2 months worth of hourly readings. The user can download the data to a computer for further analysis.

TED is very accurate and programmable. The user can input rate details, including flat fees, time-of-use or demand pricing, and taxes. Based on these data, TED can estimate the electric bill accurately. There will always be some discrepancy because the exact time of the utility read will vary.

According to President Dolph Rodenberg, future plans include being able to control loads directly from TED and adding communications capability so TED could display costs for dynamic pricing. TED also has a connection directly from the display to USB so data can be downloaded to computer for analysis.

Cost

Target cost $150. Installation costs similar to others at $75-200.

Greenwire Energy Monitor (Greenwire)

Description

The Greenwire Energy Monitor is an in-home energy display designed to provide a simple readout with very low installation costs. Rather than using a clip-on CT, which requires an electrician, the Energy Monitor collects energy consumption data via an attachment to the outside of the meter and communicates to an in-home display device. According to the inventor, the homeowner can install it. The display shows past 24 hours' energy use (kWh) and cost ($, based on a fixed average cost). Instantaneous energy use is displayed in non-numeric ways: bar graph, and a light that flashes faster when electricity use is higher. The light mimics the meter spinning faster during high usage. The display is battery operated and communicates via wireless RF, so it can be placed anywhere in the home or business and moved at any time.

The Energy Monitor is not yet commercially available. A few prototype units have been built. A product launch is planned for 1st Quarter 2005.

Figure 6: Greenwire Energy Monitor

Source: Greenwire LLC

Company and Experience

Greenwire LLC is a start-up company located in Austin, Texas. Greenwire is a joint venture between inventor Mark Palasz and Good Company Associates, a business development, advocacy and consulting company.

Installation

The Greenwire Energy Monitor was designed to be installed by the user. There is an energy use-sensing device that attaches to the outside of the existing electric meter. Greenwire chose not to disclose the technology they use for competitive reasons. They report that users can install the device themselves, so installation cost is zero.

Differentiating Features

According to Greenwire, their Energy Monitor will be very simple to use. The homeowner will simply take it out of the box, turn it on, and attach the sensing device to the meter. The display runs on batteries and can be moved around the home or business. Energy use will be shown graphically as well as numerically.

Cost

The Greenwire Energy Monitor is not yet commercially available. Target cost is $50.

Power Cost Display Monitor (Energy Control Systems)

Description

The Power Cost Display Monitor by Energy Control Systems has two components: the transmitter and the display monitor. It does not use a clip-on CT, but we include it in this section because it works with the existing utility meter. It does not require an additional or replacement meter, as it acts as a “add on” to the existing analog residential utility meter. The advantage of this approach is that it can function as a customer display device in parallel with the utility meter, without disturbing the utility meter reading or billing processes.

The transmitter is installed between the existing electric meter and the utility meter socket. Meter data are communicated over the powerline to the display monitor located in the home. The monitor is very simple. It looks a bit like a digital clock, with no function keys, and plugs into a standard electrical outlet. It displays a conversion of the current energy usage into what the energy cost would be for the whole month. That is, the cost displayed is the instantaneous energy use (kW) times the cost (cents/hour) times 24 hours/day times 30 days/month.

The PCDM received National Safety Testing Lab (NSTL) approval in December, 2004. Like the other in-home displays previously discussed, the PCDM bases cost calculations on a flat rate. The designers state they could program fixed TOU prices into the conversion upon request. But since it has no external communications interface, the device could not respond to critical peal or cannot calculate costs for real time rates.

Figure 7: Power Cost Display Monitor

Source: Energy Control Systems

Company and Experience

Energy Control Systems is a start-up company located in Incline Village, Nevada, with fewer than ten employees. They report to have provided demonstration units to several utilities, and that the City of Palo Alto has purchased ten units as a trial and will be starting a program in

January, 2005 to install PCDMs in low-income housing. Southern California Edison has tested two units in their meter shop and found them to be accurate within ANSI guidelines, and has also conducted some in home tests.

Installation

A utility electrician must install the PCDM, since it requires removing the meter in order to install. It is a meter extension socket fits between the meter and the meter panel, and measures the electrical usage of the entire residence. The display monitor is located in the residence, and can be moved around and plugged into any outlet. It communicates via power line carrier with the PCDM at the meter.

Differentiating Features

PCDM was designed for use as a means to provide direct feedback to residents, from high-end luxury homes to low-income housing. Its display is the simplest of all the monitors we studied. It shows only the " estimated monthly cost," though, as noted above, and the cost displayed is not a cost a customer would actually pay, but rather a cost if the house ran at current state for a month.

Cost

The PCDM costs about $380 in small quantities. The transmitter is installed behind the meter, so requires a utility electrician. Energy Control Systems says the entire installation should take only a few minutes. Installation costs will vary depending on locations of meters and utility labor rates.

Submetering Systems

Submetering is a much more established metering application than in-home energy displays. Manufacturers of non-utility residential submetering, such as Dent Instruments and MeterSmart (acquired E-Mon) are established companies with a wide selection of products, for whole-premise or sub loads. Their systems are highly accurate, in some cases even revenue grade. Typically, submetering systems are designed to be read using software and do not have displays. Like meters, they gather consumption data only, not energy prices.

Submeters are generally designed for either tenant billing or collecting data for further analysis. While they could be used for in-home displays, they are not that well suited to the task. They are over-designed for this use: they measure waveforms, power quality and other variables not needed for simple in-home displays. They measure power very accurately, but they do not store energy price or provide any energy cost information. They are hard-wired to the circuit panels and thus not easily accessible to users. E-Mon's kWh E-CON Meter has a simple display showing instantaneous use. It does not show use month-to-date or cost. Dent Instruments' ElitePro is similar. It currently has no display at all. Dent says they will be adding a display, but even so, cautions that the submeter is not the right vehicle for in-home display for dynamic pricing.

Meter-Based Systems

Displays that receive data flows directly from the meter by definition see the same consumption as the meter does. Questions about whether the display is accurate are minimized. At first blush, it seems that in-home display devices would be a natural product for the meter industry to offer.

The major meter manufacturers in the United States are not pursuing in-home display devices as a feature of their meters. We talked to marketing representatives from Elster Electricity, Landis+Gyr, Itron, and GE. They have no current plans to develop in-home displays, but say that if utilities are seriously interested (i.e.: interest accompanied by a request for proposals and subsequent purchase order) they would be able to develop prototypes. New meters can be purchased with under-the-glass additions from manufacturers of in-home displays. For example, the Landis+Gyr Focus meter works with the USCL EMS-2020. The Itron Centron meter works with the TWACS (formerly CIC) PowerStat in-home display for prepayment.

MTC, a start-up metering company no longer in business, tried to market a meter with an in-home display unit. A few utilities were very interested in the technology. MTC was acquired by Echelon and is no longer working on this product.

Since these technologies rely on installation of new meters to deploy the display technologies, they do not appear to be a good fit for a utility seeking to provide in-home displays to some of its customers without replacing the existing metering infrastructure. However, some of the vendors make the point that replacing a meter can be done more simply at lower cost than having an electrical contractor come to a house and install a parallel or CT-based display device.

Replacing a meter is work on the utility “right of way”. In the United States, it is often done outside the home or business and does not require the customer to be present, so it is easier to schedule. There is usually no problem gaining access to the meter panel, for replacement or meter reading. In comparison, circuit breaker panels that carry the customer energy load can be located in basements or garages. In theory, installing the clip-on CT takes only 20 minutes, but the real-life details of access to the panel can add to that time considerably. In addition, if utilities are installing devices at the panel, they must be prepared to deal with customer owned panels that are not to code or otherwise unsafe.[8]

[8] Chris Dent, President of Dent Instruments, tells datalogger installation difficulties. For example, they have opened a panel box to find water pouring down the back wall. Chris Dent, personal communication (December 13, 2004), Dent Instruments, 64 NW Franklin Avenue, Bend, OR 977041-2906, tel: 541-388-4774, email: cdent@dentinstruments.com..

EMS-2020 (USCL)

Description

The EMS-2020 is a portable display monitor that works with a Landis+Gyr Focus meter with a communications chip. It is necessary to replace the existing utility meter with the new meter. The EMS-2020 display monitor looks a bit like a TV remote control, with the addition of a full-color screen. The monitor communicates wirelessly with the metering system. In the optimal configuration, according to USCL, the meter and display unit are part of an integrated utility communications infrastructure, or AMR network.

The display gets data directly from the meter and is programmed with all components of the utility tariff. Because the meter has two-way communication with the utility, it can accurately show energy costs on a CPP tariff. It is the only display studied that reportedly presents cost information that matches the utility bill exactly. The EMS-2020's budget feature allows the customer to set a monthly dollar budget. An alarm sounds when use is predicted to exceed budget.

For geographically dense areas, the AMR network can be a fixed radio frequency. For less dense areas, USCL uses a powerline carrier technology. In either case, many additional AMR functions such as remote disconnect, tamper/theft detection, outage reporting, and meter reading, are also available. Alternatively, the EMS-2020 can be used as an in-home display, with the Landis+Gyr Focus meter.

The EMS-2020 and Focus meter combination can be used without the full AMI network. In this configuration, however, it won't have two-way communications between meter and utility, so won't be able to show costs for dynamic rates.

Figure 8: EMS-2020

Source

Company and Experience

USCL is a metering and communications company located in Sacramento, California. President Tom Tamarkin has long been involved in the areas of AMR and information display and in 1990 formed TAMAR Corporation, one of the early AMR vendors. In 1992, Tamarkin wrote an article in Public Power that posited customer display as one of many benefits of AMR: "Utilities can enhance customer relations by selling internal display units to customers that provide up-to-the-minute monitoring of power consumption, in dollars and cents. This can be used as an energy management tool and allows customers to verify and reconcile bills."[9]

USCL has a partnership with AMR company Arad Technologies of Israel for collecting data from electric, gas, and water meters. This partnership gives USCL the ability to integrate a wide-area or fixed AMR network into their product offering. USCL reports that the County of Los Angeles is deploying 360 EMS-2020s in 5 housing developments in the near future.

Installation

The EMS-2020 is part of a system that includes a new meter and RF wireless communications between the meter and the display unit. Once the advanced metering is in place, the EMS-2020 communicates wirelessly and requires no installation. However, the underlying meter with a chip that communicates with the EMS-2020, requires utility purchase and installation.

Differentiating Features

The EMS-2020 is by far the most complex of the displays studied. Its full color screen shows bar graphs of energy use. The user can choose from dozens of screens. The most unique feature is that the calculation of the energy cost will match the utility bill exactly, since all tariff components are programmed into the EMS-2020. In fact, USCL says the utility could actually implement "subscriber-side billing"--calculate the bill at the home or business, even for advanced variable rate structures, and send the bill, rather than just billing determinants, back to the head office.

The USCL system has features beyond the in-home display, such as meter reading, outage reporting, and tamper detection in real-time. It can support remote disconnect of service with an additional contactor module. It can also collect data from gas and water meters, all of which can be displayed on the EMS-2020.'

If the utility chooses not to implement a full AMR deployment, it can still leverage of the EMS-2020, but it will require installing a new meter, since the meter is the data collector for the display. As noted above, without a communication path between utility and meter, the meter/display will not be able to accurately reflect energy costs during critical peak times.

[9] Tom Taramkin, "Automatic Meter Reading," *Public Power,* September-October, 1992.

Cost

The cost of the EMS-2020 and whole USCL system is very much dependent on scale. In small quantities (~400) the cost is about $250 per home (includes meter and EMS-2020). Installation costs are the utility electrician's time for a few minutes to replace the meter. In quantities of 10,000 USCL projects costs at about $175 per home. Costs for an RF network range from $10-30 per meter, depending on geography and density.

PowerPal Meter with Customer Interface Display (Dent Instruments)

Description

The PowerPal Meter with Customer Interface (CI) Display is a combination of a Sensus iCon meter with powerline communications to the display unit. Dent Instruments is currently developing this product and expects it to be ready 3rd quarter, 2005. (They note that with a specific order, units could be ready 2nd quarter.) The CI Display can show instantaneous and cumulative use and cost. The CID is also used in the City of Tacoma's PAYGo project (see below). The meter can be programmed for TOU or demand rates. Although not currently planned, it would be possible to add a paging receiver to the meter so that it could also collect and display data for a critical peak tariff. The CI Display also has two LEDs that Tacoma can be turned on or flash to indicate price signals.

Company and Experience

Dent Instruments, formerly Pacific Science & Technology, is a well-established and respected manufacturer of equipment for electronic data acquisition, storage, analysis and presentation. Dent is headquartered in Bend, Oregon.

Installation

The replacement meter requires a few minutes of a utility electrician's time to set. The CI Display plugs directly into the wall. This type of installation may well be simpler than going into the customer's premises and attaching to the circuit panel.

Differentiating Features

To see how much energy is being used or what it costs, the users pushes a button on the CI Display. The CI Display then queries the meter and displays the requested information.

Cost

The PowerPal meter will cost about $300 in pilot quantities, less at higher volumes. The CI Display device costs $250-280. Installation will be a few minutes of a utility electrician's time to reset the meter.

Prepayment Meters

Prepayment systems have long included in-home displays, for the obvious reason that customers needed some indication of when they were about to run out of credit and power. The prepayment manufacturers have not been moving into the in-home display market for the purposes of dynamic tariffs.

Customer Interface Display (Dent Instruments)

Description

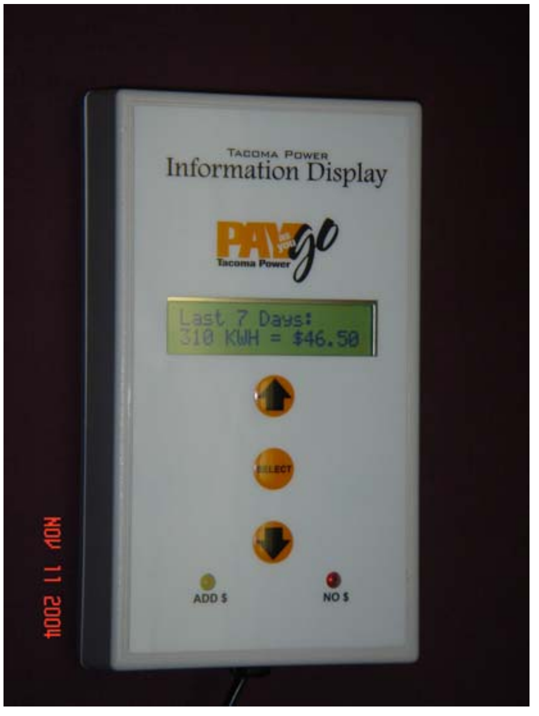
Dent Instruments is working with the City of Tacoma's Pre-Pay Metering (PAYGo) project. Tacoma has a citywide fiber network and has replaced all meters with network-interface meters. Tacoma can remotely read the meters, connect/disconnect power, etc. over the fiber network. For the PAYGo program, Tacoma needed a way to let customers see how much power/money they have left. Dent Instruments developed the Customer Interface Display for this purpose.

The Customer Interface Display is a simple unit that communicates with the utility via powerline. The user scrolls through a list of questions, finds the one he wants, and presses the button. The CI device itself has little intelligence. The text lives not on the CI device, but on the Tacoma server, so can be changed easily. Once the query is sent, the response is relayed from the Tacoma server and displayed on the device. Typical displays are: amount remaining ($ and time remaining), current use (kW and $/hr), yesterday's use (kWh and $), last 7 days' and last 30 days' use.

The CI display relies on the fiber network to be able to read the meter at any time. It is not directly applicable to the IDP. Dent Instruments has said it could incorporate a wireless receiver into the CI display to replace the powerline communication. However, it would still require some kind of always-on network to read the meter. It wouldn't work with interval meters read daily because customers couldn't see instantaneous use.

The CI Display also has two LEDs that Tacoma can turn on or flash to indicate a new message or other account information, for example that the account is running low. For a CPP tariff, the LEDs could also indicate price signals.

Figure 9: Customer Interface Display



Source: Dent Instruments

Company and Experience

Dent Instruments, formerly Pacific Science & Technology, is a well-established and respected manufacturer of equipment for electronic data acquisition, storage, analysis and presentation. Dent is headquartered in Bend, Oregon.

Installation

The CI Display plugs directly into a standard electrical outlet and requires no special setup.

Differentiating Features

The CI Display is very versatile in that in can display any message from the utility. Since the device itself communicates but queries are stored/generated at the utility server, it is extremely flexible. When the utility wants to make more information available to the customer, the query is added to the scroll list. The CI Display requires internet-connected meters, since it collects data as it is requested.

Cost

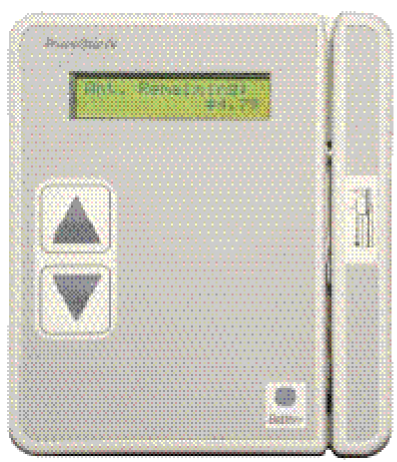
The CI Display device costs $250-280. There is no installation cost for the CI Display, since it just plugs in. It is, however, part of a prepayment metering system.

PowerStat (DCSI)

Description

PowerStat is part of a prepayment metering system. The meter is replaced with a prepayment meter, which communicates with the PowerStat display device via powerline. The display shows the current cost of electricity, the current rate of use, cost of electricity for previous day, week, and month, and amount of credit remaining. These are typical of values displayed with prepayment metering systems.

Figure 10: PowerStat



Source: DCSI

In 1995, CIC Global (now part of DCSI) worked on a pilot project with PacifiCorp to provide in-home display of electricity use and cost to about 50 customers. The display device, called the EM-1, was similar to the prepayment display except that it worked with the standard utility meter. It also had LED indicators that would light during peak rate, when the customer was under load control, or projected to exceed monthly budget. The system used Metricom communications.

According to Ken Anderson, who managed the in-home monitoring program for PacifiCorp, the system worked well. Only 50 were deployed because it was part of a larger AMR project that ultimately did not go forward. The key was to get customers to position them for easy viewing. That meant making them useful—and useful to the customer meant more than electricity use. Had the program continued, Anderson would have had the displays show time (they always had the right time because they synched daily and had batteries) and temperature. He also found that making the displays fit into the existing décor was important and was working on customized faceplates, including a few colors and a clear option that could hold a photo.[10]

Figure 11: EM-1

Source: DCSI

DCSI does not currently have an active in-home display without prepayment offering, but they are working on it. Indeed, CIC's experience with in-home display and knowledge of customer preferences for information display was a key factor in DCSI's acquisition of CIC.[11]

Company and Experience

DCSI, a provider of AMR and load control using powerline carrier technology, acquired CIC Global in July 2004. DCSI is currently working on ways to incorporate prepayment and in-home display technology with their AMR system. CIC's PowerStat is the in-home display for their prepayment system and could be modified for in-home display. In addition, CIC had an in-home display they piloted with PacifiCorp ten years ago that had many of the features of interest.

Installation

The PowerStat plugs directly into the wall. It communicates with the meter via powerline.

[10] Ken Anderson, Project Planning Engineer, Northwest Efficiency Alliance, 529 SW Third Avenue, Suite 600, Portland, OR 97204, tel 503-827-8416 ext. 249, email kanderson@nwalliance.org.
[11] Kevin Cornish, personal communication (December 14, 2004), Director, Utility Solutions, TWACS by DCSI, 66 Maryland Avenue, Berkeley, CA 94704, tel 510-528-3038, email kcornish@twacs.com.

Differentiating Features

In-home display works with existing utility meter.

Cost

The PowerStat unit works only with replacement meter. The EM-1 is not currently commercially available.

Research Technologies

Research into new ways to display information is ongoing at universities.

Energy Cube

Ken Camarata of Carnegie Mellon University works on combining tangible interfaces with calm technology, or “peripheral representation of ambient displays.” (Camerata et al 2004). His team has created two prototype energy displays. He envisions them as part of an energy kit that the utility would loan to customers. Customers would take the kit home for a month, configure a non-invasive sensor network, and see energy use information on the included displays. The occupants would see how their behaviors affect energy use. After a month, they would return the kit to the utility.

The first prototype is the Energy Cube. Each side of the cube corresponds to a zone in the house (egg: kitchen, bedroom, etc.). Inside the cube are red and blue LEDs embedded in a ping-pong ball. The ball acts as a diffuser and the color changes from blue to purple to red as energy use increases. To find out how much energy the kitchen is using, pick up the cube and rotate it so the kitchen side is up.

The prototype did not actually gather real energy use data. Instead it used a network of photocells. The varying amount of light falling on the photocells was used as a proxy for energy consumption. This demonstrated that the cube was able to change colors for the different zones. Actually gathering energy use data on a room-by-room basis is a challenge yet to be overcome.

Energy Magnets

Camarata’s second prototype is modeled after refrigerator magnets. Various household appliances have magnetic icons. The user places icons on a board and a bar graph showing energy use appears. A bar chart for whole house energy use is also shown.

Like the Energy Cube, the Energy Magnets are in the early prototype phase. Camarata notes the “represent an interesting and engaging first step.”

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Bengtson, Kevin. "Can Better Utility Bills Save Energy?" *Home Energy*, (May/June, 1997).

Identified customers preferences for on-bill information display.

Camarata, Ken, Drew Bregel, Ellen Ti-Luen Do, and Mark D. Gross. "Artifacts for Displaying Home Energy Use," presented at Generative CAD Symposium, Carnegie Mellon, July 12-14, 2004. Downloaded from http://depts.washington.edu/dmgftp/publications/pdfs/GCAD04-Energy.pdf.

Explains Energy Magnets and Energy Cube concepts.

Centre for Sustainable Energy. "Energy Matters: Home Energy Resource, Its Effects on Energy Efficiency in the Home" (April 2003).

Centre for Sustainable Energy. "Energy Education Hitting Home: A Summary of the Evaluation Report into the Impact of the Energy Matters Programme," (2004). Available at http://www.cse.org.uk/pdf/pub1025.pdf.

Over half (54%) of parents have installed energy-savings measures, including energy efficient light bulbs, appliances, and upgrading insulation. That investment rate is similar to what is seen after visits from professional energy advisors.

Parents are likely (three-quarters) to take actions to save energy after their school-age children have been educated about energy efficiency.

Darby, Sarah. "Making it Obvious: Designing Feedback into Energy Consumption," Proceedings 2nd International Conference on Energy Efficiency in Household Appliances and Lighting. Italian Association of Energy Economists. (2000)

Reviews previous literature and finds that in 21 studies (various sample size, housing type, additional interventions, feedback frequency and duration), savings after participants given direct feedback was 5 percent or greater in most cases. "Metering displays should be provided for each individual household in a form that is accessible, attractive and clear."

Darby, Sarah. “Making Sense of Energy Advice,” Proceedings, European Council for an Energy-Efficient Economy, 6.167 (2003)

Darby, Sarah. “Energy Advice—What Is It Worth?” Proceedings, European Council for an Energy-Efficient Economy, III.05 (1999)

> Reviews effects of energy advice, including more frequent meter readings. In Europe, where meters were often read semi-annually, increasing frequency of meter reads to bi-monthly, or giving customer ability to read own meter, resulted in savings of 10 percent.

Dobson, John K., and J.D. Anthony Griffin. “Conservation Effect of Immediate Electricity Cost Feedback on Residential Consumption Behavior,” Proceedings, ACEEE (1992).

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Green, J, S Darby, C Maby and B Boardman. “Advice into Action: An Evaluation of the Effectiveness of Energy Advice to Low-Income Households,” EAGA Charitable Trust (1998).

Haakana, Maarit, Liisa Sillanpää, and Marjatta Talsi. “The Effect of Feedback and Focused Advice on Household Energy Consumption,” Proceedings, ECEEE Summer Study (1997).

> Households receiving feedback on energy consumption reduced electricity consumption by 17-21 percent.

Heijne, Caroline. “Energy Education Hitting Home: Monitoring the Impact of Energy Matters,” A Report to Ofgem by the Centre for Sustainable Energy (April 2003). Available at http://www.cse.org.uk/pdf/pub1022.pdf.

> Energy Matters is an energy education program for children ages 7-14 in the UK. Three-quarters of parents changed their behavior to save energy after their children participated in Energy Matters. Almost half of them were more interested in saving energy after their children participated, and overall 90% were interested in saving energy in the home.

Hutton, R. Bruce, Gary A. Mauser, Pierre Filiatrault, and Olli T. Ahtola. “Effects of Cost-Related Feedback on Consumer Knowledge and Consumption Behavior: a Field Experimental Approach,” *Journal of Consumer Research*, v. 13: 327-336 (1986).

> Field experiments with in-home displays in US and Canada. The displays showed cumulative total cost of energy for a 24-hour period and also cost for the next hour. Customers liked and indicated willingness to pay for the devices, although their use of the devices declined after a few months. Savings in Canada were 4 to 5 percent. Savings were not found in California. Paper concludes that authors cannot prove hypothesis that any feedback to any customer will result in savings.

Kempton, Willett, and Linda L. Layne. “The Consumer’s Energy Analysis Environment,” *Energy Policy* 22 (10):857-866 (1994).

Concludes that energy data collection and analysis tasks “are currently assigned to the less efficient parties, degrading decision quality and creating a market barrier to energy conservation. We suggest a more efficient allocation of data collection and analysis between the consumer and energy utility.”

Machrone, Bill. “The Electron Leak: Why Doesn’t the ‘Off’ Button Really Turn Things Off?” PC Magazine, (October 5, 2004). Downloaded from http://www.pcmag.com/article2/0%2C1759%2C1645410%2C00.asp.

Reporter finds that his cable box, sound system, computer equipment and home theatre equipment all consumes energy, even when it’s turned off—to the tune of about 100W. He calculates that as 9 percent of his total electric bill, or $100 for the convenience of having equipment turn on right away.

Roberts, Simon and William Baker, “Towards Effective Energy Information: Improving Consumer Feedback on Energy Consumption,” A Report to Ofgem by the Centre for Sustainable Energy (July 2003). Available at http://www.cse.org.uk/pdf/pub1014.pdf.

Finds feedback on energy use to customers is “most effective when it is immediate, prominent, accessible and specific [to the customer]” and that customers can respond to historical comparison information and in-the-home meter displays.

Further, finds that in addition to relevant, engaging feedback, customers also need a “motivating justification” to act.

Concludes that Ofgen should “consider whether it can and should act to ensure new meter installations also offer the clear additional benefit of integrating quality consumption feedback to the consumer through in-the-home displays.”

Roberts, Simon, Helen Humphries and Verity Hyldon, “Consumer Preferences for Improving Energy Consumption Feedback,” A Report to Ofgem by the Centre for Sustainable Energy (May 2004). Available at http://www.cse.org.uk/pdf/pub1033.pdf.

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Siero, Frans W., Arnold B. Bakker, Gerda B. Dekker, and Marcel T.C. van den Burg. “Changing Organizational Energy Consumption Behaviour through Comparative Feedback,” *Journal of Environmental Psychology* 16 (3):235-246. (1996).

Employees in one unit of a metallurgical company received information about energy conservation, set goals, and received feedback on their behaviour. Employees of a second unit received the same information, and also information on the performance of the first unit (comparative feedback). The comparative feedback group saved more energy, even “with hardly any changes in attitudes or intentions”.

Van Houwellinger, Jeannet H. and W. Fred Van Raaij. “The Effect of Goal-Setting and Daily Electronic Feedback on In-Home Energy Use,” *Journal of Consumer Research*, v. 16: 98-105 (1989).

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Wood, G. and M. Newborough. “Dynamic Energy-Consumption Indicators for Domestic Appliances: Environment, Behaviour and Design,” *Energy and Buildings*, v. 35:8 (September 2003).

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Calm Technology

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Wenham, Chris, “Ah, the ambience,” (September 4, 2004), posted at http://www.disenchanted.com/technology/ambience.html.

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